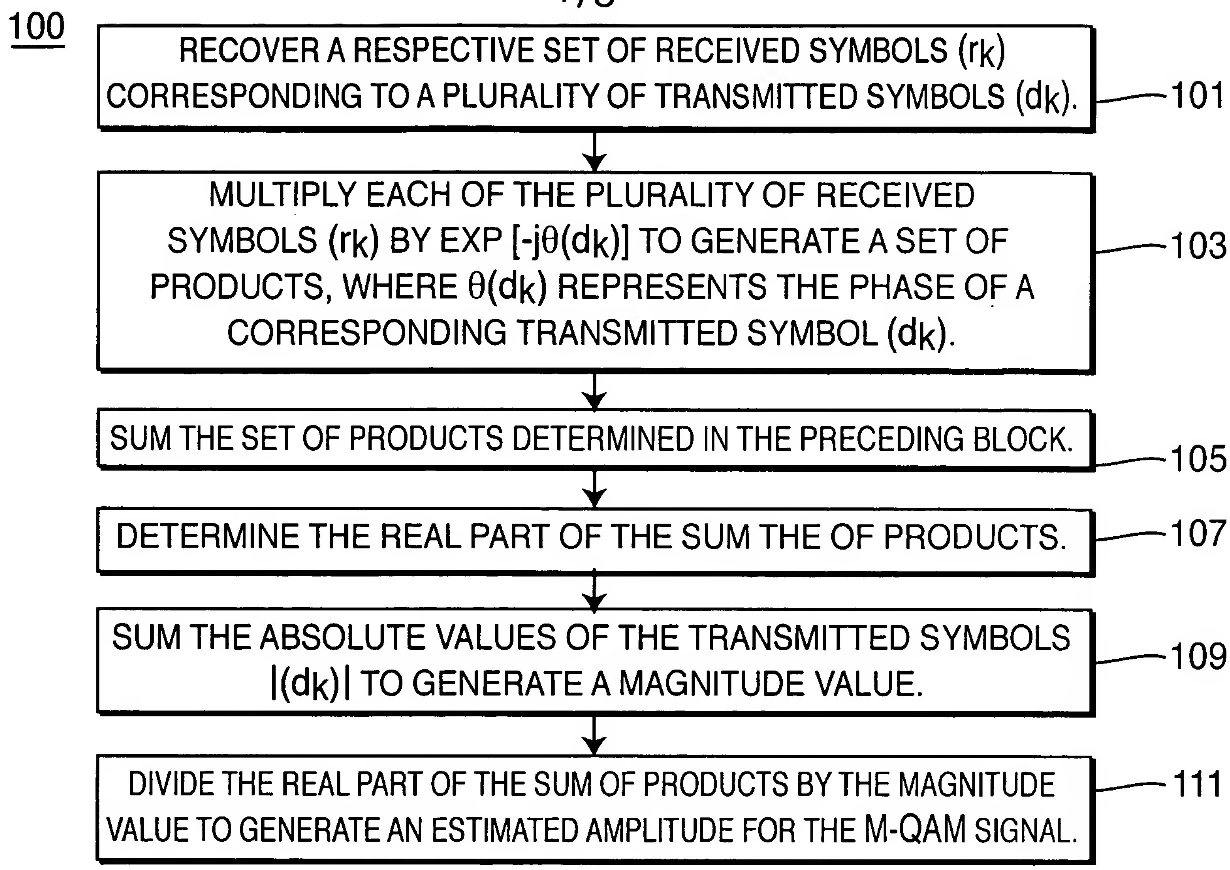
100
RECOVER A RESPECTIVE SET OF RECEIVED SYMBOLS (r_k) CORRESPONDING TO A PLURALITY OF TRANSMITTED SYMBOLS (d_k).
101
MULTIPLY EACH OF THE PLURALITY OF RECEIVED SYMBOLS (r_k) BY EXP [$-j\theta(d_k)$] TO GENERATE A SET OF PRODUCTS, WHERE $\theta(d_k)$ REPRESENTS THE PHASE OF A CORRESPONDING TRANSMITTED SYMBOL (d_k).
103
SUM THE SET OF PRODUCTS DETERMINED IN THE PRECEDING BLOCK.
105
DETERMINE THE REAL PART OF THE SUM THE OF PRODUCTS.
107
SUM THE ABSOLUTE VALUES OF THE TRANSMITTED SYMBOLS $|(d_k)|$ TO GENERATE A MAGNITUDE VALUE.
109
DIVIDE THE REAL PART OF THE SUM OF PRODUCTS BY THE MAGNITUDE VALUE TO GENERATE AN ESTIMATED AMPLITUDE FOR THE M-QAM SIGNAL.
111

FIG. 1

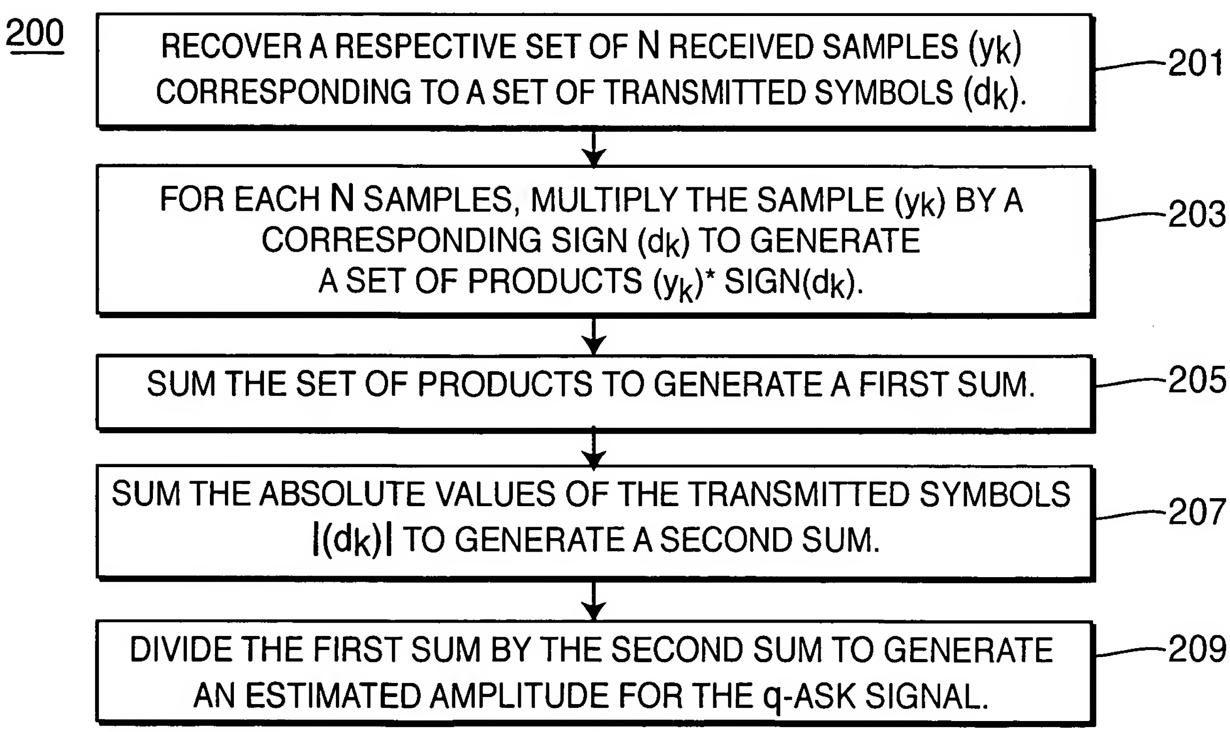
200
RECOVER A RESPECTIVE SET OF N RECEIVED SAMPLES (y_k) CORRESPONDING TO A SET OF TRANSMITTED SYMBOLS (d_k).
201
FOR EACH N SAMPLES, MULTIPLY THE SAMPLE (y_k) BY A CORRESPONDING SIGN (d_k) TO GENERATE A SET OF PRODUCTS (y_k)* SIGN(d_k).
203
SUM THE SET OF PRODUCTS TO GENERATE A FIRST SUM.
205
SUM THE ABSOLUTE VALUES OF THE TRANSMITTED SYMBOLS $|(d_k)|$ TO GENERATE A SECOND SUM.
207
DIVIDE THE FIRST SUM BY THE SECOND SUM TO GENERATE AN ESTIMATED AMPLITUDE FOR THE q-ASK SIGNAL.
209

FIG. 2

300

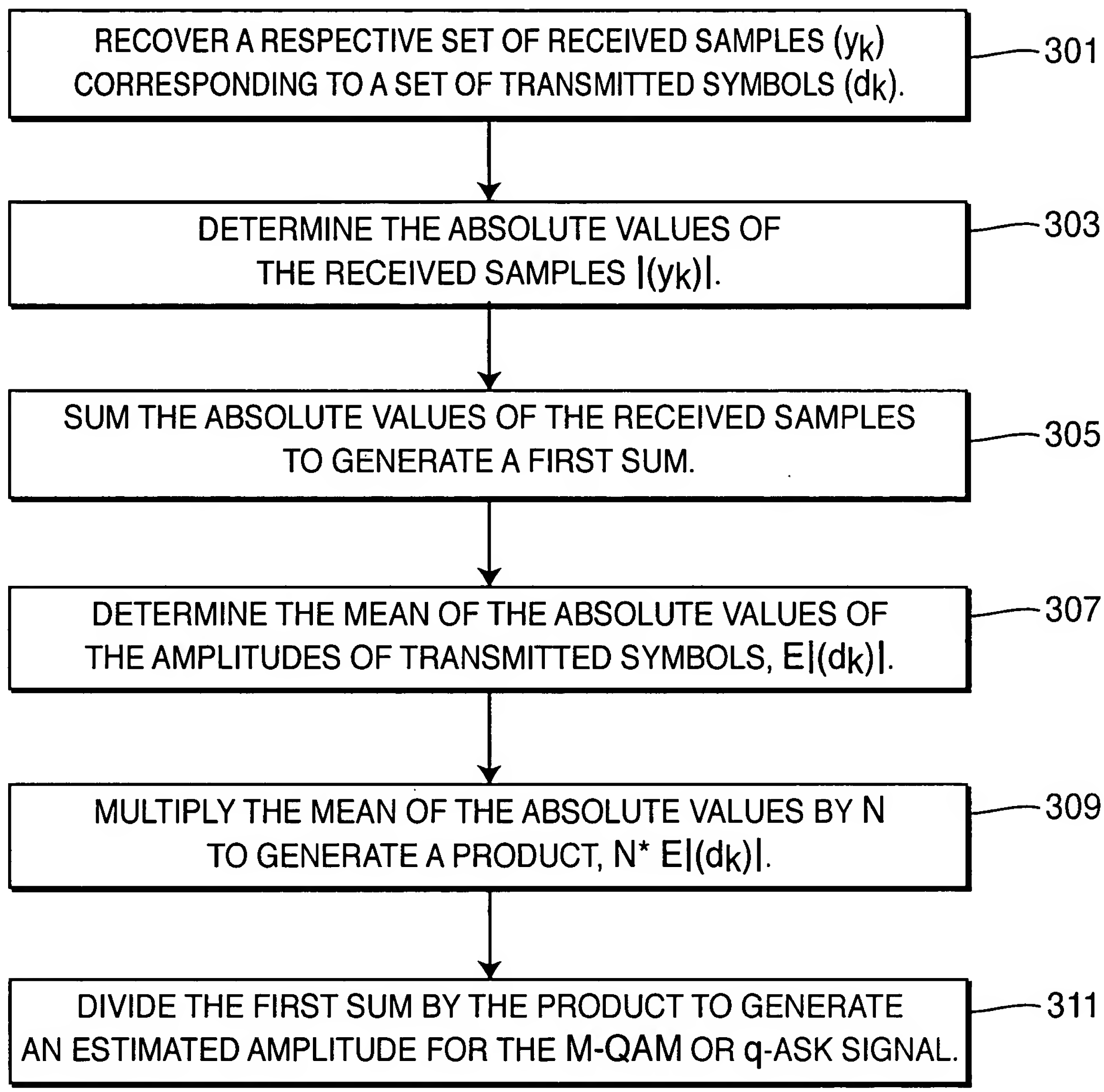
RECOVER A RESPECTIVE SET OF RECEIVED SAMPLES (y_k) CORRESPONDING TO A SET OF TRANSMITTED SYMBOLS (d_k).
301
DETERMINE THE ABSOLUTE VALUES OF THE RECEIVED SAMPLES $|(y_k)|$.
303
SUM THE ABSOLUTE VALUES OF THE RECEIVED SAMPLES TO GENERATE A FIRST SUM.
305
DETERMINE THE MEAN OF THE ABSOLUTE VALUES OF THE AMPLITUDES OF TRANSMITTED SYMBOLS, $E|(d_k)|$.
307
MULTIPLY THE MEAN OF THE ABSOLUTE VALUES BY N TO GENERATE A PRODUCT, $N^* E|(d_k)|$.
309
DIVIDE THE FIRST SUM BY THE PRODUCT TO GENERATE AN ESTIMATED AMPLITUDE FOR THE M-QAM OR q-ASK SIGNAL.
311

FIG. 3

400

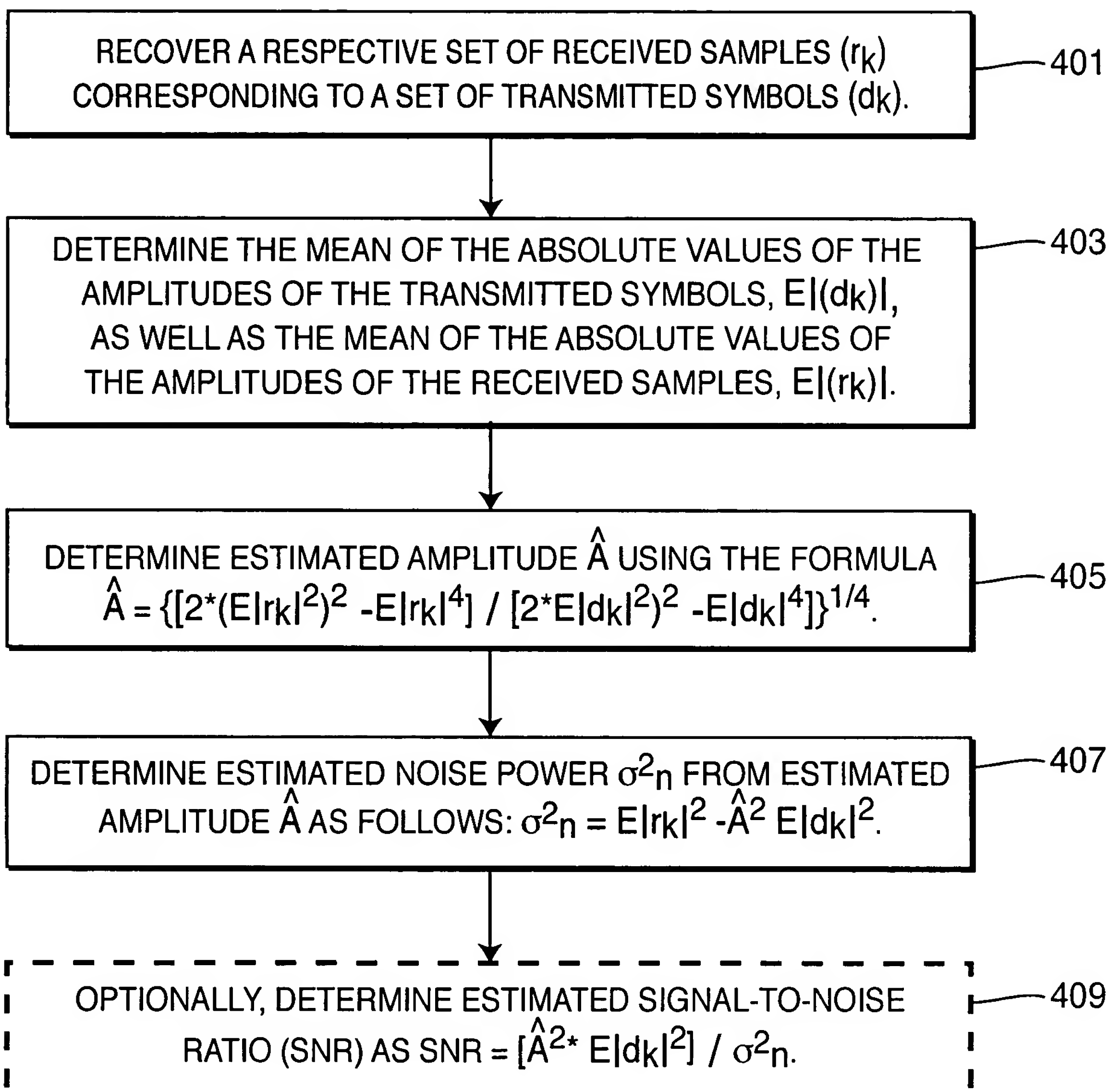
RECOVER A RESPECTIVE SET OF RECEIVED SAMPLES (r_k) CORRESPONDING TO A SET OF TRANSMITTED SYMBOLS (d_k).
401
DETERMINE THE MEAN OF THE ABSOLUTE VALUES OF THE AMPLITUDES OF THE TRANSMITTED SYMBOLS, $E|(d_k)|$, AS WELL AS THE MEAN OF THE ABSOLUTE VALUES OF THE AMPLITUDES OF THE RECEIVED SAMPLES, $E|(r_k)|$.
403
DETERMINE ESTIMATED AMPLITUDE $\hat{A}$ USING THE FORMULA $\hat{A} = \{[2^*(E|r_k|^2)^2 - E|r_k|^4] / [2^*E|d_k|^2)^2 - E|d_k|^4]\}^{1/4}$.
405
DETERMINE ESTIMATED NOISE POWER $\sigma^2 n$ FROM ESTIMATED AMPLITUDE $\hat{A}$ AS FOLLOWS: $\sigma^2 n = E|r_k|^2 - \hat{A}^2 E|d_k|^2$.
407
OPTIONALLY, DETERMINE ESTIMATED SIGNAL-TO-NOISE RATIO (SNR) AS SNR = $[\hat{A}^{2*} E|d_k|^2] / \sigma^2 n$.
409

FIG. 4

500

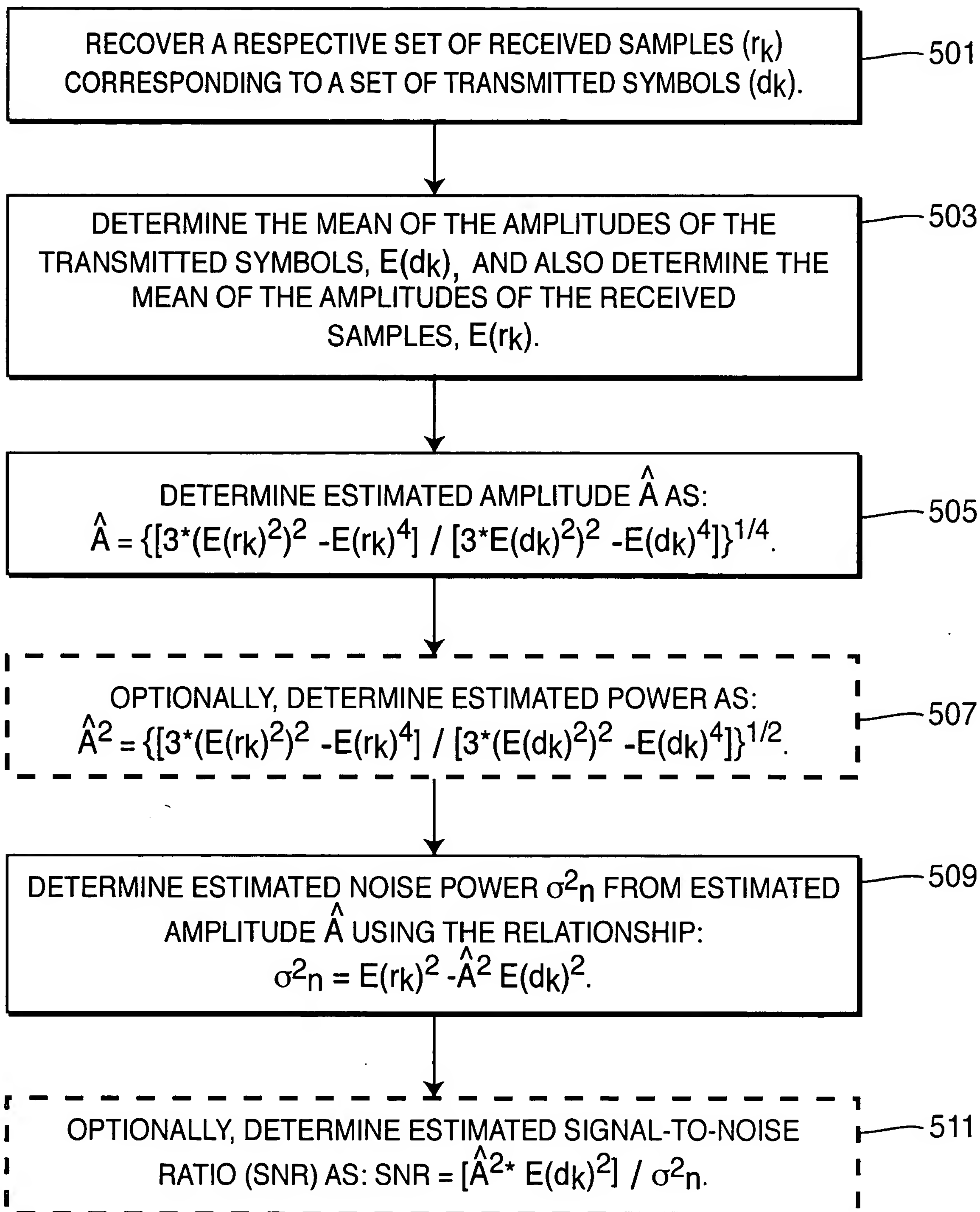
RECOVER A RESPECTIVE SET OF RECEIVED SAMPLES (r_k) CORRESPONDING TO A SET OF TRANSMITTED SYMBOLS (d_k).
501
DETERMINE THE MEAN OF THE AMPLITUDES OF THE TRANSMITTED SYMBOLS, $E(d_k)$, AND ALSO DETERMINE THE MEAN OF THE AMPLITUDES OF THE RECEIVED SAMPLES, $E(r_k)$.
503
DETERMINE ESTIMATED AMPLITUDE $\hat{A}$ AS:
$\hat{A} = \{[3^*(E(r_k)^2)^2 - E(r_k)^4] / [3^*E(d_k)^2)^2 - E(d_k)^4]\}^{1/4}$.
505
OPTIONALLY, DETERMINE ESTIMATED POWER AS:
$\hat{A}^2 = \{[3^*(E(r_k)^2)^2 - E(r_k)^4] / [3^*(E(d_k)^2)^2 - E(d_k)^4]\}^{1/2}$.
507
DETERMINE ESTIMATED NOISE POWER $\sigma^2 n$ FROM ESTIMATED AMPLITUDE $\hat{A}$ USING THE RELATIONSHIP:
$\sigma^2 n = E(r_k)^2 - \hat{A}^2 E(d_k)^2$.
509
OPTIONALLY, DETERMINE ESTIMATED SIGNAL-TO-NOISE RATIO (SNR) AS: SNR = $[\hat{A}^{2*} E(d_k)^2] / \sigma^2 n$.
511

FIG. 5

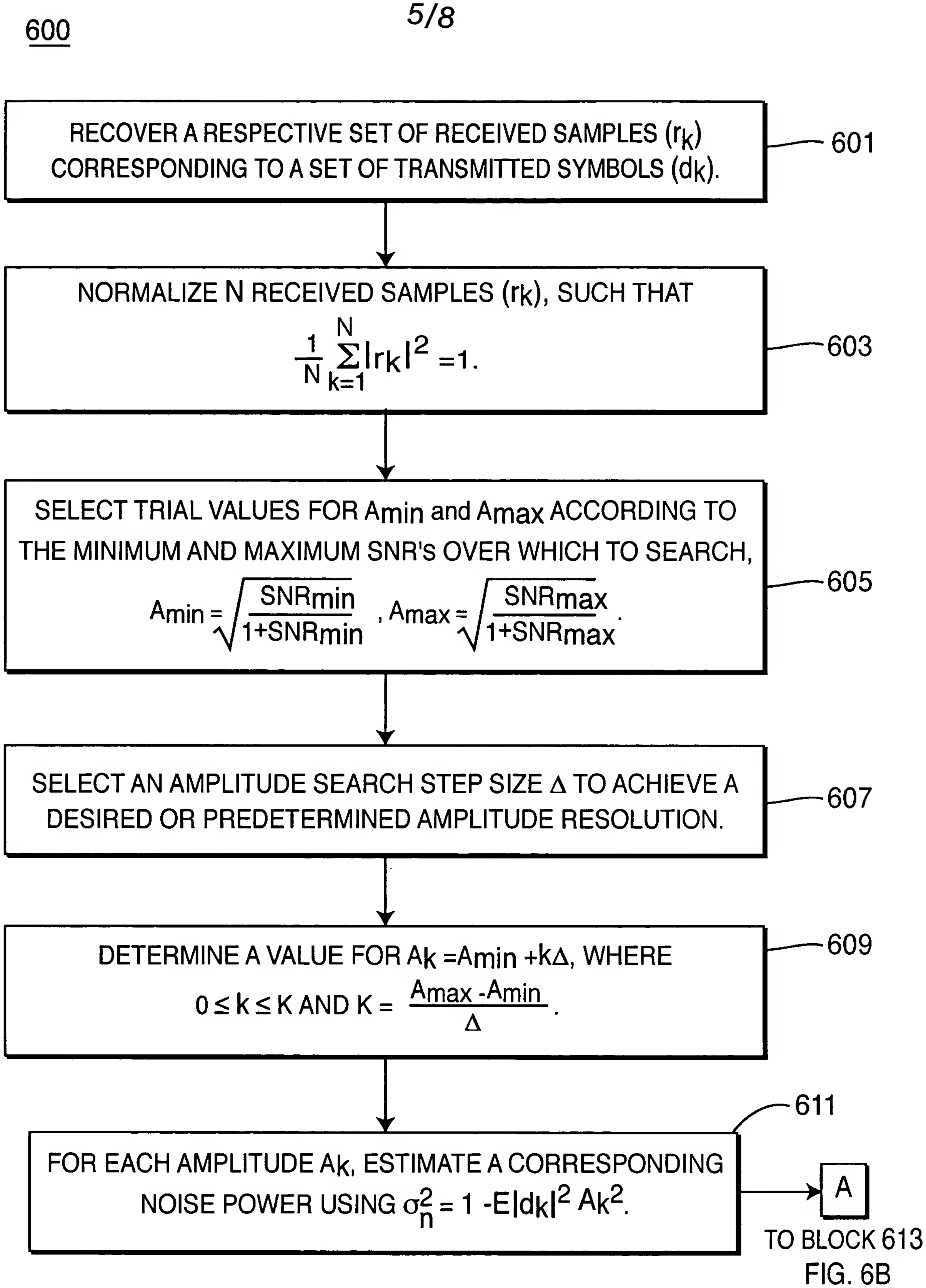
600
RECOVER A RESPECTIVE SET OF RECEIVED SAMPLES (r_k) CORRESPONDING TO A SET OF TRANSMITTED SYMBOLS (d_k).
601
NORMALIZE N RECEIVED SAMPLES (r_k), SUCH THAT $\frac{1}{N}\sum_{k=1}^{N}|r_k|^2 = 1$.
603
SELECT TRIAL VALUES FOR A_{min} and A_{max} ACCORDING TO THE MINIMUM AND MAXIMUM SNR's OVER WHICH TO SEARCH, $A_{min} = \sqrt{\frac{SNR_{min}}{1+SNR_{min}}}$, $A_{max} = \sqrt{\frac{SNR_{max}}{1+SNR_{max}}}$.
605
SELECT AN AMPLITUDE SEARCH STEP SIZE Δ TO ACHIEVE A DESIRED OR PREDETERMINED AMPLITUDE RESOLUTION.
607
DETERMINE A VALUE FOR $A_k = A_{min} + k\Delta$, WHERE $0 \le k \le K$ AND $K = \frac{A_{max} - A_{min}}{\Delta}$.
609
611
FOR EACH AMPLITUDE A_k, ESTIMATE A CORRESPONDING NOISE POWER USING $\sigma_n^2 = 1 - E|d_k|^2 A_k^2$.
A
TO BLOCK 613, FIG. 6B

FIG. 6A

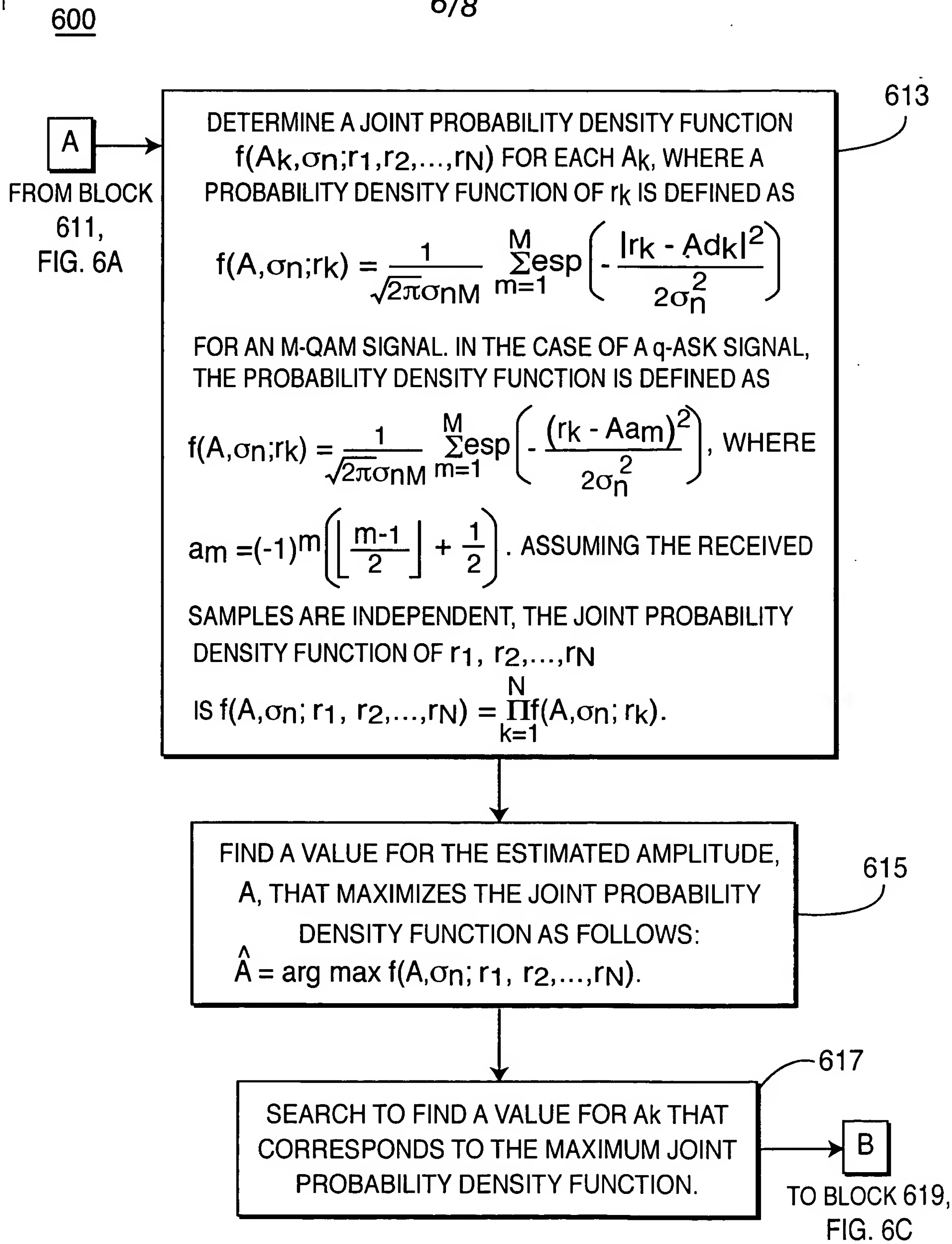
600
A
FROM BLOCK 611, FIG. 6A
613
DETERMINE A JOINT PROBABILITY DENSITY FUNCTION $f(A_k,\sigma_n;r_1,r_2,\ldots,r_N)$ FOR EACH A_k, WHERE A PROBABILITY DENSITY FUNCTION OF r_k IS DEFINED AS
$f(A,\sigma_n;r_k) = \frac{1}{\sqrt{2\pi}\sigma_n M} \sum_{m=1}^{M} esp\left(-\frac{|r_k - Ad_k|^2}{2\sigma_n^2}\right)$
FOR AN M-QAM SIGNAL. IN THE CASE OF A q-ASK SIGNAL, THE PROBABILITY DENSITY FUNCTION IS DEFINED AS
$f(A,\sigma_n;r_k) = \frac{1}{\sqrt{2\pi}\sigma_n M} \sum_{m=1}^{M} esp\left(-\frac{(r_k - Aa_m)^2}{2\sigma_n^2}\right)$, WHERE
$a_m = (-1)^m\left(\left\lfloor\frac{m-1}{2}\right\rfloor + \frac{1}{2}\right)$. ASSUMING THE RECEIVED SAMPLES ARE INDEPENDENT, THE JOINT PROBABILITY DENSITY FUNCTION OF $r_1, r_2,\ldots,r_N$
IS $f(A,\sigma_n; r_1, r_2,\ldots,r_N) = \prod_{k=1}^{N} f(A,\sigma_n; r_k)$.
615
FIND A VALUE FOR THE ESTIMATED AMPLITUDE, A, THAT MAXIMIZES THE JOINT PROBABILITY DENSITY FUNCTION AS FOLLOWS:
$\hat{A} = \arg\max f(A,\sigma_n; r_1, r_2,\ldots,r_N)$.
617
SEARCH TO FIND A VALUE FOR A_k THAT CORRESPONDS TO THE MAXIMUM JOINT PROBABILITY DENSITY FUNCTION.
B
TO BLOCK 619, FIG. 6C

FIG. 6B

600

B

FROM BLOCK 617, FIG. 6B

SUBSTITUTE THE VALUE FOR Ak DETERMINED IN THE PRECEDING STEP INTO EQUATION $\hat{A} = \arg\max f(A_k, \sigma_n; r_1, r_2, \ldots, r_N)$ TO OBTAIN A VALUE FOR $\hat{A}$, REPRESENTING AN ESTIMATED AMPLITUDE VALUE. 619

OPTIONALLY, DETERMINE A VALUE FOR ESTIMATED NOISE POWER FROM ESTIMATED AMPLITUDE $\hat{A}$ AS FOLLOWS:
$\sigma_n^2 = E(r_k)^2 - \hat{A}^2 E(d_k)^2$. 621

OPTIONALLY, DETERMINE A VALUE FOR ESTIMATED SIGNAL-TO-NOISE (SNR) FROM THE RELATIONSHIP SNR =
$[\hat{A}^2 * E(d_k)^2] / \sigma_n^2$. 623

FIG. 6C

700

A

FROM FIG. 7A, BLOCK 707

ESTIMATE SIGNAL-TO-NOISE (SNR) USING:

$$SNR = \frac{(2 - Kurt(r)) + \sqrt{(4 - 2K_{M-QAM}) - (2 - K_{M-QAM})Kurt(r)}}{(Kurt(r) - K_{M-QAM})}$$

709

FIG. 7B

700

701

DETERMINE SECOND-ORDER AND FOURTH-ORDER MOMENTS OF A SET OF RECEIVED SAMPLES (r_k). THE SECOND-ORDER MOMENT IS DEFINED AS $E\{|r_k|^2\}=E\{|n_k|^2\}+E\{|d_k|^2\}$, AND THE FOURTH-ORDER MOMENT IS DEFINED AS $E\{|r_k|^4\}=E\{|n_k|^4\}+E\{|d_k|^4\}+E\{|n_k|^2\}E\{|d_k|^2\}$, WHERE d_k DENOTES THE TRANSMITTED SYMBOLS AND n_k DENOTES A NOISE COMPONENT THAT IS RECOVERED WITH THE RECEIVED SAMPLES r_k.

703

DIVIDE THE FOURTH-ORDER MOMENT BT THE SECOND-ORDER MOMENT SO AS TO IMPLEMENT A KURTOSIS OPERATION AS FOLLOWS:

$$\mathrm{Kurt}(r) \equiv \frac{E\{|r_k|^4\}}{E\{|r_k|^2\}^2} = \frac{E\{|d_k|^4\}+E\{|n_k|^4\}+4E\{|d_k|^2\}E\{|n_k|^2\}}{E\{|d_k|^2\}^2+E\{|n_k|^2\}^2+2E\{|d_k|^2\}E\{|n_k|^2\}}$$

THE FOREGOING EXPRESSION FOR KURTOSIS INCLUDES A FIRST KUROSIS COMPONENT ATTRIBUTABLE TO THE RECEIVED SIGNAL, AND A SECOND KUROSIS COMPONENT CORRESPONDING TO THE RECEIVED NOISE.

705

DETERMINE THE SECOND COMPONENT OF KURTOSIS, CORRESPONDING TO RECEIVED NOISE, AS FOLLOWS: ASSUMING THE EXISTENCE OF COMPLEX CIRCULARLY SYMMETRIC GAUSSIAN NOISE, THE KUROSIS OF THE NOISE COMPONENT ALONE IS

$$K_{CG} \equiv \frac{E\{|n_k|^4\}}{E\{|n_k|^2\}^2} = 2.$$

707

DETERMINE THE FIRST COMPONENT OF KURTOSIS, CORRESPONDING TO THE SIGNAL, (K_{sig}), AS

$$K_{sig} \equiv \frac{E\{|d_k|^4\}}{E\{|d_k|^2\}^2}.$$

IN THE CASE OF AN M-QAM SIGNAL, K_{sig} IS DENOTED AS $K_{M\text{-}QAM}$.

A

TO FIG. 7B, BLOCK 709

FIG. 7A